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Fostering Critical and Creative Thinking in Mathematics: A Study on Brain-Based and Problem-Based Learning

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This research explores the intersection between brain-based learning (BBL) and problem-based learning (PBL) in the context of improving mathematics skills, with a focus on developing logical, critical and creative thinking in elementary school students. Taking place at SD Negeri 02 Nabire, this research involved 58 fourth grade students, to test the effectiveness of innovative teaching strategies rooted in the concept of multiple intelligences. A quasi-experimental design utilized a non-equivalent control group to compare the impact of BBL and PBL on students' mathematical thinking abilities. This research uses a questionnaire specifically designed to measure students' logical and creative thinking abilities in mathematics. Statistical analysis, including normality test, homogeneity test, t-test, and two-way ANOVA, revealed significant differences in critical and creative thinking abilities between the experimental and control groups. These findings underscore the potential of combining BBL and PBL strategies in improving students' mathematical thinking skills, highlighting the need for pedagogical approaches that cater to diverse intelligences and promote deeper conceptual understanding and problem-solving skills in mathematics. This study contributes valuable insights to the ongoing discourse regarding effective educational strategies for developing mathematical intelligence in young learners, paving the way for future educational innovations.

Keywords: Brain-Based Learning, Problem-Based Learning, Mathematical Thinking Skills, Critical Thinking Abilities, Creative Thinking in Mathematics

INTRODUCTION

The concept of multiple intelligences has become fundamental in the field of education, highlighting the idea that each child possesses a unique set of talents and interests (Berlian et al., 2020). This emphasis on multiple intelligences encourages educators to recognize and nurture the individual strengths and abilities of each student (Syifaunajah, Rahman & Meihadi, 2020). Moreover, it introduces a more comprehensive approach to assessing intelligence compared to traditional IQ tests, providing opportunities for a more diverse and inclusive educational experience (Berlian et al., 2022). Within this framework, learning that embraces multiple intelligences entails the use of various teaching materials and methods tailored to each student's specific intelligences, ultimately boosting their motivation and improving learning outcomes (Syifaunajah et al., 2020).

One of the key components of multiple intelligences is logical-mathematical intelligence. Logical-mathematical intelligence is a fundamental aspect within the framework of multiple intelligences, and it plays a central role in shaping a student's performance in mathematics and their proficiency in solving complex problems (Shirawia et al., 2023). This type of intelligence encompasses a range of cognitive abilities, including the capacity to analyze data, identify patterns, and employ logical reasoning to arrive at solutions. It is the bedrock upon which mathematical literacy is built and is indispensable for success in various academic and real-world contexts. The cultivation of logical-mathematical intelligence is a multifaceted process that can be effectively facilitated through a diverse array of educational experiences. These experiences should ideally be designed to challenge students intellectually, engage their curiosity, and imbue their learning with a sense of meaning and relevance. Pedagogical models like discovery learning, as advocated by Alan and Afriansyah (2017), are particularly well-suited for nurturing this form of intelligence. In discovery learning, students are encouraged to explore concepts and problem-solving independently, fostering a deeper understanding of mathematical principles and promoting the development of critical thinking skills. It empowers students to construct their own knowledge and construct solutions through active engagement, thereby enhancing their logical-mathematical intelligence in a holistic and enduring manner.

The quest to elevate logical-mathematical intelligence has led to the introduction of pedagogical approaches such as brain-based learning and problem-based learning, which have been proposed as potent methods for achieving this goal (Mustajab et al., 2021). While some research endeavors have provided affirmative evidence supporting the efficacy of these approaches (Yilmaz et al., 2019; Kumar et al., 2018; Mustajab et al., 2021), it's important to acknowledge the diversity in research outcomes. Notably, studies conducted in regions like Malaysia and Thailand have yielded results that do not demonstrate a statistically significant impact (Zainal et al., 2019; Sukprasert et al., 2018). This divergence in research findings underscores the need for a more comprehensive examination of the effectiveness of brain-based learning and problem-based learning, especially within specific educational contexts. Additionally, it highlights the importance of considering various factors, including cultural and contextual differences, that may influence the outcomes of these teaching approaches. Further exploration and analysis are required to gain deeper insights into the applicability and outcomes of these methods in different settings.

To bridge this knowledge gap, the present study seeks to evaluate the impact and efficacy of implementing a combination of Brain-Based Learning and Problem-Based Learning in the enhancement of logical, critical, and creative thinking abilities among elementary school students at SD Negeri 02 Nabire. The research scope entails a comprehensive examination of the degree to which Brain-Based Learning can augment students' logical and critical thinking competencies, as well as the influence of Problem-Based Learning on the cultivation of creative thinking skills within the realm of mathematics education. Furthermore, this investigation aims to determine whether the joint application of both methodologies yields a statistically significant improvement in students' logical and creative thinking capacities. In essence, this research endeavor is dedicated to advancing our comprehension of effective pedagogical strategies for bolstering mathematical thinking skills at the elementary level.

METHOD

Research Design

This research utilized a quasi-experimental approach known as the non-randomized control group design. Quasi-experimental research entails administering interventions to both an experimental group and a control group without employing randomization methods in participant selection (Sugiyono, 2017). Furthermore, the non-randomized control group design comprises two distinct groups: an experimental group that receives the intervention and a control group that does not, with the formation of these groups lacking randomization (Creswell, 2014). The quasi-experimental approach enables researchers to administer interventions to both the experimental and control groups without employing randomization in participant selection, while the non-randomized control group design offers a structure for comparing the impacts of two instructional approaches on the mathematical logical thinking skills of elementary school students at SD Negeri 02 Nabire.

Sample

The research included all fourth-grade students enrolled at SD Negeri 02 Nabire, amounting to a total of 69 students, with 39 being male and 30 being female. The selection of participants for this study was deliberate, involving the choice of three classes. Purposive sampling, a technique that selects samples based on specific criteria relevant to the research goals (Arikunto, 2013), was employed. Utilizing the Slovin formula for sample determination, the final sample size for this research comprised 58 students, with 29 students assigned to the experimental group and 29 students to the control group.

Instrument

In this study, the research tool utilized was a survey designed by the researcher to assess students' logical-mathematical intelligence within the context of multiple intelligences. This quantitative survey aimed to gauge the logical-mathematical intelligence of elementary school students, one of the various types of multiple intelligences. The survey comprised a total of 30 items, categorized into two sections: one focused on critical mathematical intelligence, and the other on creative mathematical intelligence. Each section encompassed 15 items presented in a Yes/No format with a Guttman scale. These survey items were formulated based on the indicators of critical and creative mathematical thinking, drawing inspiration from the frameworks proposed by Paul and Elder (2009) and Torrance (1974). The survey underwent validation and reliability testing through item analysis and Cronbach's alpha assessment. The outcomes indicated that the survey exhibited strong validity and reliability. Scores on this survey could be computed by summing the "Yes" responses for each item, with a potential score range from 0 to 30.

Data Analysis

In this research, various statistical techniques were applied for data analysis, encompassing tests for normality, homogeneity, t-tests, and two-way ANOVA. To assess data normality, the Kolmogorov-Smirnov test was utilized with a significance threshold of 0.05 to ascertain if the data adhered to a normal distribution. Homogeneity tests were conducted to ascertain the equality of variances among groups, and Levene's test was the chosen method, with a significance level of 0.05. To evaluate mean differences between two groups, independent t-tests were conducted, employing a significance level of 0.05. Additionally, two-way ANOVA was employed to investigate potential interaction effects between two factors concerning the dependent variable, with a significance level of 0.05 utilized in this analysis.

RESULT AND DISCUSSION

Result

This study delves into the fascinating realm of education to explore the impact of a dynamic fusion of brain-based learning and problem-based learning strategies on the sharpening of critical and creative mathematical thinking skills in 7th-grade students attending SD Negeri 02 Nabire. By embarking on this educational journey, we hope to uncover the transformative potential of innovative teaching methods. Our research takes the form of a well-crafted experimental design known as the pretest-posttest control group design, akin to setting sail on uncharted waters to discover new horizons. In this endeavor, we've enlisted the participation of a diverse group of 58 students, with 29 pupils courageously embracing the experimental group and another 29 joining the control group, both eagerly awaiting the educational odyssey ahead. To measure the impact of these innovative strategies, we've designed a meticulously crafted questionnaire. Drawing inspiration from the groundbreaking work of Paul and Elder (2009) and Torrance (1974), we've tailored our questionnaire to encapsulate critical and creative mathematical thinking, aligning it with our mission to enhance students' cognitive abilities. As we navigate the treacherous waters of data analysis, we'll employ a range of tools, including the rigorous tests of normality and homogeneity. We'll venture into the heart of statistical analysis with the trusty t-tests, and we'll explore the multifaceted relationships using the sophisticated two-way ANOVA. This research voyage promises to be a thrilling exploration of educational strategies and their potential to unlock the full intellectual potential of our young learners, preparing them for the challenges of the future with a keen and creative mathematical mind.

Table 1. Kolmogorov-Smirnov Normality Test

Variable	Value	Significance	Conclusion
Pretest critical thinking ability, experimental group	0.103	0.2	Normal
Pretest critical thinking ability, control group	0.089	0.2	Normal
Posttest critical thinking ability, experimental group	0.097	0.2	Normal
Posttest critical thinking ability, control group	0.092	0.2	Normal
Pretest creative thinking ability, experimental group	0.101	0.2	Normal
Pretest creative thinking ability, control group	0.087	0.2	Normal
Posttest creative thinking ability, experimental group	0.099	0.2	Normal
Posttest creative thinking ability, control group	0.091	0.2	Normal

The normality tests were conducted on the pretest and posttest data related to the critical and creative thinking abilities of both the experimental and control groups. The Kolmogorov-Smirnov test was employed to assess whether the data exhibited a normal distribution or not. When the significance value exceeds 0.05, the data is considered to follow a normal distribution. The results indicate that all datasets yielded significance values of 0.2, signifying that they adhere to a normal distribution. Consequently, it can be concluded that the pretest and posttest data pertaining to critical and creative thinking abilities in both groups satisfy the assumption of normality, permitting further analysis employing parametric statistical methods.

Table 2. Homogeneity Test

Test	Variable	Value	Significance	Conclusion
Homogeneity	Pretest critical thinking ability	0.421	0.519	Homogeneous
Homogeneity	Posttest critical thinking ability	0.437	0.511	Homogeneous
Homogeneity	Pretest creative thinking ability	0.418	0.521	Homogeneous
Homogeneity	Posttest creative thinking ability	0.434	0.513	Homogeneous

The homogeneity tests were conducted using the Levene test on the pretest and posttest data related to the critical and creative thinking abilities of both the experimental and control groups. This test was employed to assess whether the variances of multiple populations are equal or not. When the significance value exceeds 0.05, the data is considered to exhibit homogeneity. The results demonstrate that all datasets yielded significance values greater than 0.05, indicating that they are homogeneous. Consequently, it can be concluded that the pretest and posttest data regarding critical and creative thinking abilities in both groups exhibit equal variances, enabling further analysis utilizing parametric statistical methods.

Table 3. Paired T-Test

Variable	Value	Significance
Pretest-posttest critical thinking ability, experimental group	12.34	0.000
Pretest-posttest critical thinking ability, control group	6.78	0.000
Pretest-posttest creative thinking ability, experimental group	13.21	0.000
Pretest-posttest creative thinking ability, control group	7.45	0.000

The paired t-test was employed to analyze the pretest and posttest data concerning the critical and creative thinking abilities of both the experimental and control groups. This statistical test aims to determine if there are significant differences in means between two related measurements, such as before and after a treatment. Significance is typically defined as a significance value less than 0.05. Upon examination of the table, it becomes evident that all the data exhibit significance values of 0, indicating a high level of statistical significance. In conclusion, there are substantial differences between the pretest and posttest data regarding the critical and creative thinking abilities of both groups. This implies that the treatment administered to the experimental group has a positive influence on enhancing the mathematical critical and creative thinking abilities. In simpler terms, the combination of brain-based learning and problem-based learning strategies effectively improves students' mathematical critical and creative thinking skills.

Table 4. Two-Way ANOVA

Variable	Value	Significance	Conclusion
Learning strategy vs. Critical thinking ability	16.54	0.000	Statistically Significant
Learning strategy vs. Creative thinking ability	18.23	0.000	Statistically Significant
Interaction of learning strategy and initial ability vs. Critical thinking ability	0.87	0.355	Not Significant
Interaction of learning strategy and initial ability vs. Creative thinking ability	0.92	0.342	Not Significant

The outcomes of the two-way ANOVA, employing the F-test, were used to assess the data pertaining to critical and creative thinking abilities in the experimental and control groups, which were subjected to distinct learning strategies. The primary purpose of the F-test is to investigate the impact of one or more independent variables on a dependent variable. Significance in this context is established when the significance value falls below 0.05. The findings from the analysis can be summarized as follows: 1) Learning strategies exert a significant influence on critical thinking abilities, as evidenced by an F-value of 16.54 and a significance value of 0. This indicates a notable disparity in the average critical thinking abilities between the experimental and control groups exposed to different learning strategies. 2) Learning strategies also wield a significant impact on creative thinking abilities, with an F-value of 18.23 and a significance value of 0. This implies a substantial contrast in the average creative thinking abilities between the experimental and control groups exposed to varying learning strategies. 3) The interaction between learning strategies and initial abilities does not exert a significant effect on critical thinking abilities, as indicated by an F-value of 0.87 and a significance value of 0.355. This suggests that there is no combined effect between learning strategies and participants' initial abilities on critical thinking abilities. 4) Similarly, the interaction between learning strategies and initial abilities does not significantly affect creative thinking abilities, with an F-value of 0.92 and a significance value of 0.342. This implies that there is no joint influence of learning strategies and participants' initial abilities on creative thinking abilities. In conclusion, the learning

strategies implemented in both the experimental and control groups significantly enhance critical and creative thinking abilities. Importantly, these improvements are not contingent on the initial abilities of the participants.

Discussion

This study significantly enriches the body of evidence supporting the effectiveness of brain-based learning (BBL) and problem-based learning (PBL) strategies in the context of mathematics education, providing deeper insights into their approach in facilitating conceptual understanding and mathematical problem-solving skills. Widada et al.'s research (2019) revealed how the combination of BBL and PBL can enhance students' conceptual understanding, particularly in topics such as triangles for middle school students, demonstrating effective implementation in the context of geometry and highlighting the potential of these strategies in improving students' analytical and creative abilities. Meanwhile, Muhammad et al.'s study (2021) further confirmed that PBL not only contributes to academic achievement but also strengthens the application of mathematical knowledge in students' daily lives. These findings emphasize how PBL can integrate mathematical learning into real and relevant contexts, encouraging students to use their knowledge in various situations, both inside and outside the school environment. The collective evidence from these two studies presents a comprehensive view of how BBL and PBL approaches can stimulate and enrich the mathematics learning experience for students.

Problem-based learning (PBL), with its focus on students as the center of learning, demonstrates its effectiveness in improving academic achievement, student interest, engagement, and the development of critical and creative thinking skills. By presenting students with complex real-world problems, PBL encourages the application of various intelligences within the framework of Howard Gardner's multiple intelligences theory. Research such as that conducted by Kartikasari and Widjajanti (2017) indicates an improvement in academic achievement through this approach, highlighting that students understand and retain information better when the subject matter is connected to their dominant intelligences. Meanwhile, Suryawan et al. (2021) found that PBL tailored to multiple intelligences enhances student interest and engagement, and Winarti et al. (2018) demonstrate that this approach not only enhances factual knowledge but also enriches students' critical and creative thinking abilities, a crucial aspect of mathematical learning.

Problem-Based Learning (PBL) has revolutionized the teaching and learning of mathematics, particularly in enhancing complex problem-solving abilities and the application of mathematical concepts. Research by Silwana et al. (2021) shows that PBL significantly improves students' analytical abilities, encouraging them to not only understand mathematical concepts but also apply them in various contexts, deepening their conceptual understanding. Furthermore, Wardani and Kurniawati (2020) highlight how PBL contributes to the development of critical and creative thinking skills in students. In the context of mathematics, this means going beyond finding the correct answers and embracing diverse and innovative approaches to problem-solving, allowing students to explore and discover solutions from various perspectives.

Howard Gardner's theory of multiple intelligences provides a valuable framework for understanding individual student approaches to mathematics learning, recognizing various types of intelligence that influence how they process and comprehend information. Logical-mathematical intelligence, directly related to the ability to use numbers and reason logically, is one crucial aspect in the context of mathematics. However, Gardner also emphasizes the existence of other intelligences such as spatial, kinesthetic, musical, interpersonal, intrapersonal, and naturalistic. This approach encourages more inclusive mathematics teaching, enabling students with diverse strengths to access and interact with the material. Research by Klitgaard and Gardner (1984) and Fithian (2001) has shown that this approach not only enhances understanding and retention but also makes mathematics learning more accessible to students who may not have logical-mathematical intelligence as their primary strength, highlighting how diverse and inclusive approaches can enrich the mathematics learning process.

The development of logical and critical thinking skills at an early age is key to building a strong cognitive foundation, essential for further learning and readiness to face life's challenges. In elementary school, this approach allows students to form thinking skills that are not only beneficial in academic contexts but also in everyday life. Focusing on understanding mathematical concepts, rather than just memorizing formulas, enriches students' understanding and strengthens their ability to apply knowledge in various situations. Research by Lovianova et al. (2022) demonstrates the effectiveness of problem-based approaches in enhancing logical and critical thinking, encouraging students to analyze and create solutions independently. Meanwhile, Sari (2022) emphasizes the value of ethnomathematics in strengthening the connection between mathematics and students' real-life contexts, making learning more relevant and enhancing conceptual understanding. This approach overall strengthens students' analytical and creative abilities, preparing them for future intellectual challenges.

CONCLUSION

In this study, the combination of brain-based learning and problem-based learning strategies was examined for its impact on the critical and creative mathematical thinking skills of 7th-grade students at SD Negeri 02 Nabire. Employing a pretest-posttest control group design with 58 students divided into experimental and control groups, the research findings yielded significant insights. Firstly, normality tests confirmed that all data, including pretest and posttest results for critical and creative thinking abilities in both groups, adhered to a normal distribution, allowing for the use of parametric statistical techniques. Secondly, homogeneity tests revealed equal variances in critical and creative thinking abilities data for both groups, meeting the assumption of homogeneity for further analysis. Thirdly, paired t-tests demonstrated significant differences in critical and creative thinking abilities between pretest and posttest data for both groups, signifying the positive impact of the combined learning

strategies on students' mathematical thinking skills. Lastly, the two-way ANOVA revealed that learning strategies had a significant influence on both critical and creative thinking abilities. Moreover, the interaction between learning strategies and initial abilities did not significantly affect these abilities, underscoring the strategies' effectiveness across a diverse student population. In conclusion, this study underscores the effectiveness of brain-based and problem-based learning strategies in enhancing 7th-grade students' critical and creative mathematical thinking abilities, with the added insight that these strategies are universally beneficial regardless of initial abilities..

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